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Original Communication

Fire-related fatalities in Istanbul, Turkey: Analysis of 320 forensic autopsy cases

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ABSTRACT

In this retrospective autopsy study fire-related deaths whose autopsies were carried out in the Council of Forensic Medicine in Istanbul, Turkey were analyzed in order to evaluate the relationship between the mode of the death and the laboratory and autopsy findings. There were 320 fire-related fatalities constituting the 2.07% of all autopsy cases of that period. Of the 320 cases 228 (71.3%) were males and 91 (28.4%) were females, average age in age-determined group was 36.6 (SD: 21.98) ranging from 8 months to 98 years.

Carbon monoxide intoxication played role in death of 104 cases (32.5%) either directly or together with other factors such as burning and lack of oxygen. In 32 cases (10.0%) burning was the only cause of death and in 90 cases (28.1%) burning and related complications during treatment period caused death. In 35 cases (10.9%) traumatic factors other than those related to fire were responsible for death. There were 31 cases of homicide (9.7%) and 20 cases of suicide (6.3%). Accidents constituted the majority of the cases in our autopsy population with a frequency of 51.9%.

The relationship between the presence of soot in trachea or esophagus and the mode of death and that of CO-Hb and the mode of death was statistically significant. The internal findings and laboratory data of the study population were discussed particularly on the basis of the decision of vitality in burned cases.

1. Introduction

Fire remains one of the major causes of morbidity and mortality all over the world. In 1999, in UK, 650 fire fatalities were reported, whereas in US, 7500 deaths/year was reported to result from fire. In studies of fire fatalities, authors concluded that the very young and the elderly are the most at risk, and more males are affected than females and cigarette smoking is a recognized risk factor especially in house and motor vehicles fires.[1–3]

Approximately 70% of all fire deaths occur in the home and accident is the usual reason of the fire. But, since approximately 10% of the cases are estimated to result from a fire that was deliberately started, all fire deaths should be treated as suspicious and the cause of the fire should be investigated.[4] For this investigation process of a fatal fire, a multidisciplinary approach including an appropriate scene examination, autopsy and toxicological investigation is essential.

Suicidal burning or death by self-immolation is rare and homicide by burning is uncommon. It is generally the case in which an otherwise murdered victim is burned in order to conceal the body.[5]

In the forensic assessment of burned bodies the question whether the victim was exposed to the fire before or after death is of crucial importance. The most important internal signs of vitality in burned bodies are soot deposits in the respiratory tract, the esophagus and the stomach as well as the elevated levels of CO-Hb in the blood.

In this study we aimed to document the post-mortem findings of fire-related fatalities and to evaluate the relationship between the mode of death and autopsy and laboratory findings which form the basis of assessment of these cases in forensic autopsies.

2. Materials and methods

The autopsy reports from the Council of Forensic Medicine, Istanbul, Turkey between January 1998 and September 2002 were reviewed retrospectively. All cases of burn-related fatalities in this time period were analyzed. The autopsies of fire victims between September 2002 and March 2003 were performed by the authors of this study. Thus, totally 320 cases of fire burn-related fatalities were analyzed both retrospectively and prospectively. These cases constituted the 2.07% of all autopsy cases (15 418) of the time period studied.

In these 320 cases, following parameters were noted: age, sex, cause and mode of death (accident, suicide, homicide), vital signs (hyperemic lines, respiratory soot, Hb-CO saturation), degree of burning (graded as mild, moderate, heavy; where mild means a burn area of 0–20%, moderate 21–50% and heavy 50% and more),

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traumatic findings other than burns such as skull fracture, finding of toxicological analysis and use of accelerating materials.

In treated cases, histopathological analysis of brain, liver, lung, kidney, heart and skin was performed at the laboratories of pathology department of the Council. The Hb-CO saturations were grouped as follows: 0–10%, 11–50%, >50% (considered lethal).

In analysis of data obtained, Pearson's chi square test was used. SPSS-PC 11.5 (Statistical package, IBM) was used in application of tests.

3. Results

There were 320 fire burn cases among the total 15,418 autopsies performed in the Turkish Council of Forensic Medicine between January 1998 and March 2003. These cases constituted the 2.07% of all autopsy cases of that period.

3.1. Sex

Of the 320 cases 228 (71.3%) were males and 91 (28.4%) were females. In one case, sex determination on the basis of external and internal examination was not possible due to being heavily charred.

3.2. Age

In 23 cases, age could not be estimated. Average age in age-determined group was 36.6 (SD: 21.98) ranging from 8 months to 98 years. Mean age in males was 34.7 (SD: 19.1) and 41.0 in females (SD: 27.2). Mean age was determined to be higher in female group and this difference was statistically significant ($p = 0.02$) (Table 1).

3.3. Time period

When the distribution of cases in terms of time period was taken into consideration, there were 42 cases (13.1%) in 1998, 64 (20.0%) in 1999, 67 (20.9%) in 2000, 60 (18.8%) in 2001, 55 (17.2%) in 2002 and 32 (10%) in 2003 (January–March) (Fig. 1). The relationship between gender and distribution of cases over years was found to be statistically insignificant.

Table 1
Distribution of fire victims according to the age groups and gender.

Age groups	Gender		Total
	Male	Female	
0–5	17 (5.7%)	9 (3.0%)	26 (8.8%)
6–15	15 (5.1%)	10 (3.4%)	25 (8.4%)
16–20	11 (3.7%)	3 (1.0%)	14 (4.7%)
21–25	27 (9.1%)	9 (3.0%)	36 (12.1%)
26–30	20 (6.7%)	10 (3.4%)	30 (10.1%)
31–35	28 (9.4%)	5 (1.7%)	33 (11.1%)
36–40	23 (7.7%)	4 (1.3%)	27 (9.1%)
41–45	15 (5.1%)	2 (.7%)	17 (5.7%)
46–50	13 (4.4%)	1 (.3%)	14 (4.7%)
51–55	9 (3.0%)	6 (2.0%)	15 (5.1%)
56–60	8 (2.7%)	5 1.7%	13 (4.4%)
61–65	2 (.7%)	2 (.7%)	4 (1.3%)
66–70	7 (2.4%)	5 (1.7%)	12 (4.0%)
71–75	6 (2.0%)	3 (1.0%)	9 (3.0%)
76–80	5 (1.7%)	7 (2.4%)	12 (4.0%)
81–85	2 (.7%)	4 (1.3%)	6 (2.0%)
86–90	0 (.0%)	3 (1.0%)	3 (1.0%)
>90	0 (.0%)	1 (.3%)	1 (.3%)
Total	208 (70.0%)	89 (30.0%)	297 (100.0%)

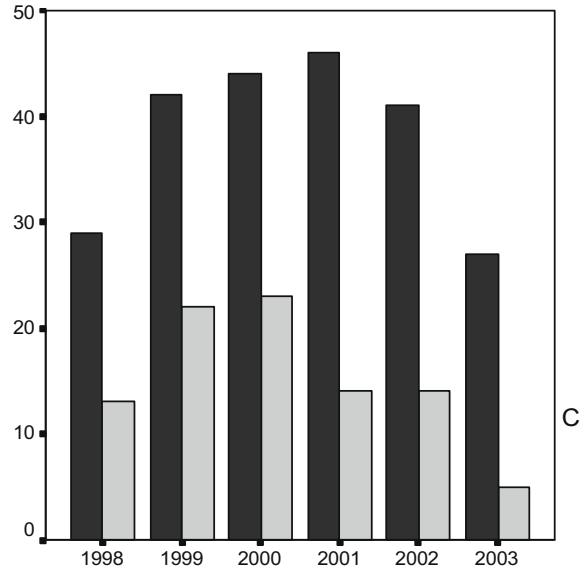

Fig. 1. Distribution of fire victims in years (Black: Male; Grey: Female).

In terms of seasons, most of the cases accumulated in winter (40.9%) and total number of the cases was lower in summer (14.7%) (Fig. 2).

3.4. Identity determination

28 cases (8.8%) were still unidentified at the time of autopsy report. These unidentified cases are waited in the Mortuary for a certain period and then buried by the municipality. Identity determination is then carried out via the photographs and DNA analysis when needed. In homicide cases, identity determination was found to be very difficult and this difference was statistically significant ($p = 0.004$). This finding shows the effort of assailant to destroy the evidences and hide the identity of the victim (Table 2).

There was heavily burn in the face, being the body portion that plays a critical role in identification process, in 143 cases (44.7%) (Table 3). In these cases identification via the facial appearance could not be possible. There was a statistically significant relationship between identification and the degree of facial burns ($p = 0.02$). In (n) (64.3%) of unidentified cases the face region was so heavily burned that identification via the facial appearance was not possible. In other words, in cases whose facial characteristics were not heavily changed due to burn, identification via facial appearance was possible in the majority (94.4%).

There was a statistically significant relation between the degree of burns in head region of the body and identification of face and it

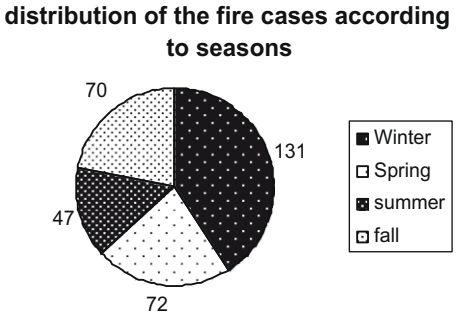

Fig. 2. Distribution of the cases according to months.

Table 2
The relationship between the origin of the fire and the identification of the victims.

Origin of the case	Victim identificated?		Total
	Yes	No	
Accident	156	10	166
Suicide	20	0	20
Homicide	23	8	31
Other	93	10	103
Total	292	28	320

Table 3
The relationship between the facial identification and identification process.

Identified?	The face of the victim is identifiable?		Total
	Yes	No	
Yes	167	125	292
No	10	18	28
Total	177	143	320

was determined that identification of face was difficult especially in cases with burns over 7% in the head region (Table 4).

3.5. Cause of death

Carbon monoxide intoxication played role in death of 104 cases (32.5%) either directly or together with other factors such as burning and lack of oxygen. In 32 cases (10.0%) burning was the only cause of death and in 90 cases (28.1%) burning and related complications during treatment period caused death. In 14 cases, burning and lack of oxygen together played role in death process (Table 5).

Burning was found to contribute the death process either directly or indirectly in 240 cases (75.0%). In 18 cases (5.6%), the level of burning was detected not to be fatal and in these cases the cause of death was lack of oxygen and carbon monoxide intoxication.

In 35 cases (10.9%) traumatic factors other than those related to fire were responsible for death (gunshot wounds, strangulation, blunt traumatic wound, sharp force trauma, etc.).

3.6. Mode of death

There were 31 cases of homicide (9.7%) and 20 cases of suicide (6.3%). Accidents constituted the majority of the cases in our autopsy population as well, being 166 cases (51.9%). In 103 (32.2%) of the cases, the fire resulted from judicial interventions against rebellion in prisons and explosions. These cases were collected under the heading "others" (Tables 6 and 7).

3.7. The cause of death and mode of death

A statistically significant correlation was detected between the cause and mode of death ($p = 0.0001$). In accidental fire cases the death of 145 victims (45.3%) was directly related to the fire itself and only in 8 (2.5%) cases it was resulted from traumatic factors. In 20 (6.3%) suicidal self-immolation cases, the death was due to severe burns. In 3 (1.1%) of the total 31 (9.7%) of the homicidal cases, the death was fire-related; in 25 (7.8) of these cases, it was directly related to traumatic reasons (not fire) and in three cases the exact cause of death could not be detected despite the fact that the origin of these three cases were homicide (Table 8).

Table 4
The relationship between the degree of burn in head region and facial identification.

	The face of the victim is identifiable?		Total
	Yes	No	
% Of the burn in head region			
1–3	45	0	45
4–6	50	3	53
7–9	44	133	177
Total	139	136	275

Table 5
The cause of death.

Death causes	Number	%
Burn	32	10.0
Burn, co intoxication and smoke inhalation	46	14.4
Burn and smoke inhalation	14	4.4
Burn and CO intoxication	58	18.1
Stab wounds	4	1.3
Co intoxication and smoke inhalation	18	5.6
Complications related to burn in the treatment course	90	28.1
Undetermined	16	5.0
Ligature strangulation	2	.6
Firearm wounds	13	4.1
General body trauma	8	2.5
Cardiovascular disease and autoerotic asphyxia	1	.3
CO intoxication	8	2.5
Stab wounds and burn	1	.3
Blunt head trauma	3	.9
Blunt head trauma, fatal pressure on neck and stab wound	1	.3
Blunt head trauma and fatal pressure on neck	1	.3
Fatal pressure on neck	1	.3
Cardiovascular disease	1	.3
Respiratory failure	1	.3
Blunt head trauma, fatal pressure on neck and burn	1	.3
Total	320	100.0

Table 6
Origin of the fire fatalities.

Origin	*n*	%
Accident	166	51.9
Suicide	20	6.3
Homicide	31	9.7
Unknown	103	32.2
Total	320	100.0

Table 7
Classification of the fires.

The type of the fire incident	*n*	%
Accidental house and workplace fires	150	46.9
Suicidal self burning	20	6.3
Homicidal burn before or after the murder	31	9.7
Car fires after traffic accident	16	5.0
Fires started during the judicial intervention in the prison	12	3.8
Arson	6	1.9
Fires started after bombing	4	1.3
Unknown	81	25.3
Total	320	100.0

3.8. Vitality signs

The presence of hyperemic lines between the burned and intact skin was detected in 86 (26.98%) cases (Table 9). In 172 cases (53.8%) there was respiratory soot in trachea, main bronchi or esophagus (Table 10). CO levels of the cases are shown in Table 11. In the cases where the CO level over 50%, the origin of the death was detected to be accident, arson or other causes such as judicial interventions against rebellion in prisons.

Hb-CO levels in suicidal cases were detected to range between 1 and 10 in 70%; 11 and 50 in 30% of the cases (Table 12).

Table 8
The relationship between the cause of death and the origin.

Cause of death	Origin of the incident				Total
	Accident	Suicide	Homicide	Other	
Fire related trauma	145	20	3	98	266
% Among the cause of death	54.5%	7.5%	1.1%	36.8%	100.0%
% Among the origin of death	87.3%	100.0%	9.7%	95.1%	83.1%
% İn total	45.3%	6.3%	.9%	30.6%	83.1%
Traumatic	8	0	25	2	35
% Among the cause of death	22.9%	.0%	71.4%	5.7%	100.0%
% Among the origin of death	4.8%	.0%	80.6%	1.9%	10.9%
% İn total	2.5%	.0%	7.8%	.6%	10.9%
Other causes	13	0	3	3	19
% Among the cause of death	68.4%	.0%	15.8%	15.8%	100.0%
% Among the origin of death	7.8%	.0%	9.7%	2.9%	5.9%
% İn total	4.1%	.0%	.9%	.9%	5.9%
Total	166	20	31	103	320
% Among the cause of death	51.9%	6.3%	9.7%	32.2%	100.0%
% Among the origin of death	100.0%	100.0%	100.0%	100.0%	100.0%
% İn total	51.9%	6.3%	9.7%	32.2%	100.0%
Fire-related trauma	145	20	3	98	266
Traumatic	8	0	25	2	35
Other causes	13	0	3	3	19
Total	166	20	31	103	320

Table 9
The frequency of hyperemic lines around the burned skin borders.

Presence of hyperemic lines?	*n*	%
Yes	86	26.9
No	10	3.1
Undeterminable	14	4.4
No record	210	65.6
Total	320	100.0

Table 10
Presence of respiratory soot.

	n	%
Yes	172	53.8
No	104	32.5
Undeterminable	17	5.3
No record	27	8.4
Total	320	100.0

Table 11
Blood level of CO-Hb.

	n	%
0–10%	72	22.5
11–50%	123	38.4
>50%	24	7.5
Total	219	68.4
No record	101	31.6
Total	320	100.0

Table 12
The relationship between the level of CO-Hb in blood and the origin of fire.

Blood level of CO-Hb	Origin of the fire				Total
	Accident	Suicide	Homicide	Other	
1–10%	23	2	8	12	45
>10%	91	3	7	46	147
0%	12	5	5	5	27
Total	126	10	20	63	219

3.9. The degree of the burns

The degree of the burns in the victims found in a fire environment in Istanbul was shown in the table (Table 13). There was no case of first degree-burn case in this autopsy series.

3.10. Skull fractures and other traumatic findings

In 50 cases (15.6%), skull fractures and deformation in skull bones due to fire were detected. In 25 cases (7.8%) firearm wounds, stab wounds and blunt traumatic lesions were detected (Table 14). The traumatic findings were due to trauma other than fire in 8.4% of the cases.

3.11. Toxicological findings

Routine toxicological analysis was carried out in 320 cases and alcohol was detected in 55 cases (17.2%). There was a statistically significant correlation between the gender and presence of alcohol. Male cases constituted the majority of alcohol-determined cases (Table 15).

In 57 cases, chemical analysis for presence of accelerants and this analysis revealed the presence of accelerants in 23 cases (7.18%). But, there was no statistically significant correlation between the presence of accelerants and the origin of the death (Table 16).

3.12. The relationship between the origin of death and vital signs

3.12.1. The hyperemic lines and the nature of death

The presence of hyperemic lines between the intact and burned skin was reported in 96 cases. The relationship between the nature

Table 13
The degree of the burns.

	n	%
Second degree	40	12.5
Third degree	97	30.3
Carbonization	183	57.2
Total	320	100.0

Table 14
Traumatic findings.

	n	%
Burn-related skull fracture, bone defects	50	15.6
Firearm wound	7	2.2
Blunt trauma	15	4.7
Stab wound	3	.9
No traumatic finding	245	76.6
Total	320	100.0

Table 15
Presence of alcohol.

	Frequency	%
Alcohol (+)	55	17.2
Alcohol (−)	202	63.1
Total	257	80.3
No record	63	19.7
Total	320	100.0

Table 16
The relationship between the presence of accelerants and the origin of death and gender.

	Origin of the incident				Total
	Accident	Suicide	Homicide	Other	
Accelerants detected on the clothing and/or skin patches					
Yes	11	1	0	11	23
No	17	3	4	10	34
Total	28	4	4	21	57

Table 17
The relationship between the origin of the incident and the presence of hyperemic lines.

	The origin of the incident				Total
	Accident	Suicide	Homicide	Other	
Hyperemic lines					
Yes	50	5	9	22	86
No	1	0	9	0	10
Total	51	5	18	22	96

Table 18
The relationship between the presence of respiratory or gastric soot and the origin of the fire.

Presence of respiratory or gastric soot	Origin of the fire				Total
	Accident	Suicide	Homicide	Other	
Yes	109	5	2	56	172
No	39	13	20	32	104
Total	148	18	22	88	276

of death and the presence of hyperemic line was found to be statistically significant ($p = 0.0001$) (Table 17).

3.12.2. The presence of soot in trachea or esophagus

The relationship between the presence of soot in trachea or esophagus and the nature of death is shown in Table 18. This relationship was statistically significant ($p = 0.0001$). In majority of homicide cases, there was no respiratory soot whereas in accidental cases the presence of respiratory soot was prominent.

3.12.3. CO-Hb level and the nature of death

The relationship between the CO-Hb level and the nature of death is shown in Table 12. The relationship was detected to be statistically significant ($p = 0.0001$). In the cases whose CO-Hb level over 50%, the origin was detected to be accident, arson or explosion. In suicidal cases, CO-Hb level was between 1% and 10% in 70% of the cases and 11% and 50% in 30% of the cases.

4. Discussion

Being mostly a retrospective study, certain limitations particularly the information about the causes of the fires and the fire environment should be acknowledged. For these reasons, the cause of the fire had to be classified as unknown in a relatively large group.

The rate of annual deaths related to fire is about 4 per million inhabitants in Istanbul, Turkey. The rate of annual deaths related to fire was reported to be about 13 per million inhabitants in the United States and Canada, and 6 per million inhabitants in Germany.[6]

There were 320 fire burn cases among the total 15,418 autopsies performed between January 1998 and March 2003 in Istanbul. These cases constituted the 2.07% of all autopsy cases of that period. The preponderance of male cases in our autopsy population was also detected in fire-related deaths. Males constituted 71.3% of the cases and females 28.4%. In one case sex determination on the basis of external and internal examination was not possible due to being heavily charred. The preponderance of male cases can be explained by the male-dominant social makeup of the community.

Copeland[1] investigated 108 fire deaths in Miami. He found a relatively even distribution between the age groups, apart from those less than five and above 70 years of age. In Rodge's study[2] a cluster of elderly people was also found and they explained this distribution reflecting the reduced ability to escape due to old age. In the Copenhagen study the same phenomenon was noted, where victims between 15 and 35 years constituted the smallest group.[3] In contrast to the finding of these studies, elderly group constituted the smallest group in this study. The most crowded group was 21–35 groups in our study. In our study average age in age-determined group was 36.6 ranging from 8 months to 98 years. Mean age in males was 34.7 and 41.0 in females. Mean age was determined to be higher in female group and this difference was statistically significant. Mean age was reported to be 44 in Park's study[4] and Gök[7] reported the most crowded group in fire deaths to be in 30–49 age groups.

Distribution of fires according to seasons showed a marked increase in winters (40.9%) and this figure is attributable to the widespread use of stoves for heating in this season. This figure was also reported by Sarı et al. in a previous study in Istanbul. Therefore, an increased awareness of the potential danger of use of stoves as a fire source and widespread use of natural gas for heating will lead to reduction in stove-related fires in Istanbul.

Fire-related fatalities are reported to be mostly in accidental origin, followed by suicides. Homicides with subsequent burning of the victim or killings by burning are comparatively rare in Europe, United States and Japan.[8–10] Homicidal burnings are reported to be often in India or South Africa.[5,11–13] In our study, there were 31 cases of homicide (9.7%) and 20 cases of suicide (6.3%). Accidents constituted the majority of the cases in our autopsy population as well, being 166 cases (51.9%). In 103 (32.2%) of the cases, the fire resulted from judicial interventions against rebellion in prisons and explosions. The high incidence of the fires in winters and the high percentage of accidental origin points out the need of use of more safe heating system in Istanbul.

A statistically significant correlation was detected between the cause and mode of death ($p = 0.0001$). In accidental fire cases the death of 145 victims (45.3%) was directly related to the fire itself and only in 8 (2.5%) cases it was resulted from traumatic factors. In 20 (6.3%) suicidal self-immolation cases, the death was due to severe burns. In 3 (1.1%) of the total 31 (9.7%) of the homicidal cases, the death was fire-related; in 25 (7.8%) of these cases, it was directly related to traumatic reasons (not fire) and in three cases the exact cause of death could not be detected despite the fact that the origin of these three cases were homicide.

In forensic assessment of burned bodies the question whether the victim was exposed to the fire before of after death is of crucial importance.[14] The basis of this assessment is a careful evaluation of vitality signs during the autopsy. Soot deposits in the respiratory tract, the esophagus and the stomach, CO-Hb levels in the blood are evaluated for this purpose. The most important constellation of findings to prove that the victim was alive during a fire is the combination of a CO–Hb concentration above 10% and the aspiration of soot.[14–16]

In our study, the presence of hyperemic lines between the intact and burned skin was reported in 96 cases. The relationship be-

tween the nature of death and the presence of hyperemic line was found to be statistically significant ($p = 0.0001$). The relationship between the presence of soot in trachea or esophagus and the mode of death was statistically significant ($p = 0.0001$). In majority of homicide cases, there was no respiratory soot whereas in accidental cases the presence of respiratory soot was prominent. The relationship between the CO-Hb level and the mode of death was detected to be statistically significant ($p = 0.0001$). In the cases where CO-Hb levels over 50%, the origin was detected to be accident, arson or explosion. In suicidal cases, CO-Hb level was between 1% and 10% in 70% of the cases and 11% and 50% in 30% of the cases. In 12 of the accidental fire deaths, in spite of evidence that the deceased was alive when the fire started there was no CO in the blood. In these cases the death was attributed to oxygen deficiency or CO_2 poisoning. In only two of the homicide victims there was respiratory soot and in 39 of 109 accidental deaths there was no respiratory soot. In these accidental fire deaths, the omnipresence of respiratory soot may be attributed to a rapid death due to flash fire.

Gormsen et al.[3] studied 169 fire fatalities and they found neither carbon monoxide in the blood nor soot in the respiratory tract in seven of the cases, in spite of evidence that the victim was alive when the fire started, which is in accordance with our data. They suspected that the cause of death in these cases may have been CO_2 poisoning or O_2 deficiency, alternatively heat. Hirsch et al.[17] have described absence of carbon monoxide in flash fire victims in five and six cases respectively. Shkrum and Johnston[18] examined 32 deaths due to self-immolation. At least 28 of these victims had used an accelerant. Three victims had a Hb-CO saturation less than 14% and two individuals had no respiratory soot. Similar findings were also reported by Rodge and Olving[2] and accordingly, these studies report similar large variations in CO-Hb saturation and respiratory soot in flash fire victims like in our study.

Routine toxicological analysis was carried out in 320 cases and alcohol was detected in 55 cases (17.2%). There was a statistically significant correlation between the gender and presence of alcohol. Male cases constituted the majority of alcohol-determined cases. This figure is also consistent with the higher frequency of alcohol abuse in our male population.

In 57 cases, chemical analysis for presence of accelerants was carried on and this analysis revealed the presence of accelerants in 23 cases (7.18%). But, there was no statistically significant correlation between the presence of accelerants and the origin of the death.

As a conclusion, certain limitations about the use of vitality parameters such as respiratory soot and blood CO-Hb saturation must be taken into consideration in evaluation of fire victims and all the findings obtained during the death scene examination, findings of the internal examination together with the findings obtained via the toxicological analysis must be interpreted together in the decision of fire deaths.

Conflicts of interest

No Conflicts of interest for our article.

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Ethical approval

This study was carried out upon permission by the Scientific Committe of the Council of Forensic Medicine.

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